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If We Teach Them, They Can Learn: Young Students Views of Nature of Science During an Informal Science Education Program

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Abstract There have been substantial reform efforts in science education to improve students' understandings of science and its processes and provide continual support for students becoming scientifically literate (AAAS, Benchmarks for science literacy, Oxford University Press, New York, 1993; NRC, National Academy Press, Washington, DC, 1996; NSTA, NSTA position statement: The nature of science, www.nsta.org/159&psid=22, 2000). Despite previous research, it is still unclear whether young children are actually developmentally ready to conceptualize the ideas that are recommended in the reforms (Akerson and Volrich, J Res Sci Teach 43:377–394, 2006). The purpose of this study was to explore how explicit-reflective instruction could improve young students' understanding of NOS. During an informal education setting, the authors taught NOS aspects using explicit-reflective instruction. Overall the students participating in the program improved their understanding of the target aspects of NOS through use of explicit reflective instruction. However, the levels of improvement varied across different aspects. Students improved the most in their understanding of the tentative nature of science and the roles of observation in scientific work, although there was still some confusion regarding the distinction between observation and inference. More work needs to be done exploring these specific topics and the role explicit reflective practice can play in identifying the particular problems students have in distinguishing these constructs.

Keywords Elementary education · Science · Nature of science · Explicit-reflective instruction · V-NOS

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Introduction

Essential to teaching science is teaching aspects of nature of science (NOS) (Abd-El-Khalick et al. 1998; Akerson and Donnelly 2009; Carey and Smith 1993; Duschl 1990; Lederman 2007; Lederman et al. 2002; McComas 1996; McComas et al. 2006; Schwartz and Lederman 2004; Walls 2009; Zeidler et al. 2002). There have been substantial reform efforts in science education to improve students' understandings of science and its processes and provide continual support for students becoming scientifically literate (AAAS 1993; NRC 1996; NSTA 2000). According to Anderson (2007), "Scientific literacy is a term that can be used to designate the science-related knowledge, practices, and values that we hope students will acquire as they learn science" (p. 5). A central component of scientific literacy is NOS (DeBoer 2000). The construct of NOS has been advocated as an important goal for student studying science for approximately 100 years (Central Association of Science and Mathematics Teachers 1907). Lederman and O'Malley (1990) referred to NOS as the epistemology of science: the values and beliefs. By focusing science instruction on the aspects of NOS educators promote, "lifelong learning, and a valuing of the kind of knowledge that is acquired through a process of careful experimentation and argument, as well as a critical attitude toward the pronouncements of experts" (Carey and Smith 1993, p. 235). Lederman (2007) refers to NOS as the epistemology of science, the values and beliefs inherent to the development of scientific knowledge, or science as a way of knowing. By promoting this type of learning, NOS instruction can create a space for all students to be successful in science.

Throughout the years, many researchers have discovered explicit reflective instruction is crucial for both teachers and students to develop understandings of NOS aspects (Abd-El-Khalick and Lederman 2001; Abd-El-Khalick et al. 1998; Akerson et al. 2000; Akerson and Donnelly 2009; Akerson and Volrich 2006; Gess-Newsome 2004; Khishfe and Abd-El-Khalick 2002; Scharmann et al. 2005; Smith et al. 2000). Explicit reflective instruction "should be planned for instead of being anticipated as a side effect or secondary product" (Akindehin 1988, p. 73), meaning forethought into the types of questions to be asked and how the aspects are going to be explicitly taught are essential to effective NOS instruction. The reflection component of explicit reflective instruction includes providing students with opportunities to reflect on the class activities regarding the different NOS aspects. This reflection piece is critical for students and teachers to develop an understanding of how science is a way of knowing or their epistemology of science (Gess-Newsome 2004; Khishfe and Abd-El-Khalick 2002). By explicitly teaching certain aspects of NOS, teachers can ensure that the same attention is given to NOS aspects as is given to the traditional science content which is critical for students to become both scientifically literate and active citizens in their community.

Despite previous research, it is still unclear whether young children are actually developmentally ready to conceptualize the ideas that are recommended in the reforms (Akerson and Volrich 2006). Although some studies demonstrated early elementary students do not naturally develop an understanding of NOS when using inquiry instruction (Akerson and Abd-El-Khalick 2005), other researchers (Akerson et al. 2000, 2007; Akerson and Donnelly 2009; Carey 1986; Carey and Smith 1993;

Metz 2004; Sandoval 2003; Smith et al. 2000) found young students were able to conceptualize many aspects of NOS in a similar informal science format using explicit reflective instruction. We believe that with the appropriate instruction students can learn NOS aspects. However, the extent to which they can develop these views and the specific views that are attainable still remains a question (Akerson and Donnelly 2009).

Purpose and Research Questions

The aspects of NOS targeted in this study include an understanding that scientific knowledge is tentative, subjective, empirically based, socially embedded, and dependent on human imagination and creativity; an additional aspect involve the distinction between observation and inference (Lederman and Lederman 2004). The purpose of this study was to explore how explicit-reflective instruction could improve young students' understanding of NOS. The specific question that guided the study was:

1. To what extent can K-2 students improve their understanding about target NOS aspects (Science is based on observations and inferences; Science is empirically-based; Science is culturally-based; Science is tentative but reliable; Science is subjective; Science is a creative endeavor) through the use of explicit reflective instruction during a 6-week informal science program?

Conceptual Framework

We based our conceptual approach to teaching the course and the study on an instructional approach that intended to teach NOS to elementary students. As previously described, explicit reflective instruction needs to accompany scientific inquiry teaching methods (Akerson and Donnelly 2009). Although there are two approaches, (1) implicit and (2) explicit reflective approaches, to improve learners' understanding of NOS aspects several research studies supported the explicit reflective instruction approach as a more effective teaching technique to foster adequate views of NOS in both pre-service and in-service elementary teachers (e.g., Abell et al. 2001; Abd-El-Khalick et al. 1998; Akerson et al. 2000; Akerson and Volrich 2006; Khishfe and Abd-El-Khalick 2002).

Explicit reflective instruction is not only an effective approach to improve teachers' view of NOS, there is evidence showing that this approach also influences elementary students' understanding of NOS (Carey et al. 1989; Khishfe and Abd-El-Khalick 2002; Akerson et al. 2000; Akerson and Donnelly 2009; Akerson and Volrich 2006; Khishfe and Abd-El-Khalick 2002) found the teaching method also promotes sixth graders' learning of NOS. After experiencing the explicit reflective science activities, the students were able to articulate informed views of NOS including tentative, empirical, inferential, and imaginative and creative NOS. Akerson and Volrich (2006) concluded that through explicit reflective instruction, first graders were able to improve their views of inferential, tentative, and creativity NOS. However, the question still remained how younger elementary students' views of NOS would change when engaging in explicit reflective instruction. To answer this question, Akerson and Donnelly (2009) performed a study using this instructional technique tailored to K-2 students in an informal science setting. Although kindergarten students developed only adequate views of the tentative and empirical NOS, the higher-grade levels tend developed adequate views of more aspects. Thus, the question remains of whether the kindergarteners were developmentally ready to attain more views or if they just did not develop the views during this program.

Khishfe and Abd-El-Khalick (2002) clearly explained that the key concept of "explicit reflective NOS instruction" is to emphasize learners' awareness of certain NOS aspects in relation to the science-based activities in which they are engaged. The pattern of the instruction begins with introducing the target NOS aspects. Next, the learners experience a science-based activity where they are allowed to conduct their investigations and experiments. After an activity, students are provided opportunities to analyze the activities in which they are engaged from various perspectives including a NOS framework. For instance, Akerson and Donnelly (2009) focused on observation and inference, evidence, and creativity of NOS. After completing NOS activities, K-2 students were asked to reflect how they were like scientists during the activity. The current study used this instructional approach with explicitly teach NOS aspects through an inquiry approach along with adequate time for the students to reflect. Examples of how explicit reflective instruction was used are on pages 9–12.

Methods

We used a qualitative approach based on the VNOS procedures (Lederman et al. 2002) to determine our students' views and changes of NOS throughout the course. We collected data using a variety of methods to determine the students' views and changes of views throughout the course. The following is a description of the intervention, data collection and analysis.

Intervention

We conducted this research in the Saturday Science program at a large midwestern university. The 6-week Saturday Science program provided local students in grades K-8 an opportunity to explore a variety of science topics through hands-on inquiry based activities. Experienced classroom teachers and university faculty, who are assisted by pre-service elementary teachers from the School of Education, taught the classes. Each weekly session was 2.5 h long, which provided extended time for investigations of science ideas. This informal science education setting allowed the researchers the ability to reflect and emphasize NOS over an intensive 6 week course as well as giving the researchers the flexibility to adapt the lessons plans weekly based on their reflections. However, the setting was similar to informal science education settings in that the activities were all hands-on, did not focus on correct terminology, fostered individual student engagement by following their interests, and did not formally assess the students for a grade. As well, we included activities that fostered a student-centered curriculum (see Table 1) to encourage the students to explore and develop questions.

Participants

The 25 students who attended the K-2 Saturday Science class we taught ranged from kindergarten to second grade. We had 19 students whose parents signed consent forms and agreed to participate in the study. Of these students, five were kindergarten students, eight were first grade students, and six were second grade students. Four of the kindergarten students were male, one was female, seven of the first grade students were male, one was female and all of the second grade students were male. Seven students were non-native speakers. Parents enrolled their students on a voluntary basis, and students are largely drawn from the university community surrounding the campus. Two students were on a scholarship, which means they received free tuition due to low SES and seven students received reduced tuition because they lived in community housing. The other students paid $75 to participate in the program. Half of the students had participated in a similar program at the university the previous spring, which was also focused on NOS aspects.

Instructors

Author 1 taught middle and high school science for 6 years in the United States and in Cambodia and has taught Saturday Science twice (grades K-2 and 3–5). Author 2 has 2 years of experience conducting NOS research with in-service teachers, and has taught K-2 as part of the Saturday Science program twice. Author 2 participated in science curriculum design for K-12 students and teaching in-service teachers in Thailand for 6 years. Author 3 is a former K-3 elementary teacher and taught Saturday Science three times (K-2 and 3–5). Authors 1 and 2 received a $375 stipend each for teaching the 6-week course.

Description of the Course

The title of our specific course was “Invention Convention: Nature of Science Put into Action.” The science content for this course focused on six aspects of the NOS (Lederman and O’Malley 1990) within the context of scientific inventions that help people travel around our world such as cars, airplanes, rockets, and bridges. These NOS aspects were: science is: (a) based on observations and inferences, (b) empirically-based, (c) culturally-based, (d) science is tentative but reliable, (e) science is subjective, and (e) science is a creative endeavor. These aspects were chosen because of their relationship to National Science Teachers Association (NSTA 2000) position statement that recommends young children understand that science is tentative, subjective (theory laden) culturally-embedded, creative and imaginative, based on empirical evidence and is a product of observation and inference. Additionally, previous research indicated that young children were able to develop these understandings (Akerson and Donnelly 2009; Akerson and Volrich

Table 1 Activity table with corresponding NOS aspects emphasized each week

Week #/topic	Activities by week	NOS aspects emphasized each week
1/NOS and wheels	1. Views of nature of science form D	1. Pretest
	2. Read color of me book	2. What is science?
	3. Nature of me activity	3. What is science?
	4. Classroom discussion of wheels	4. Observations
	5. Nature of wheel	5. Relating NOS to wheels
	6. Good wheel/bad wheel drawings	6. Observation vs. inference
	7. Create a wheel	7. Inference and subjectivity
	8. Test wheel	8. Empirical evidence
	9. Presentation of wheels	9. Cultural
2/Cars	1. Read cars of the past book	1. Tentative
	2. Classroom discussion of cars	2. Observations
	3. Draw a picture of a car they will create	3. Tentative
	4. Create a car/prediction of distance will travel	4. Creative
	5. Test car-measuring distance	5. Empirically-based
	6. Presentation of cars	6. Subjectivity
	7. Discussion of invention of other things due to cars (such as stoplights)	7. Inferences
3/Bridges	1. Read book about bridges	1. Observations
	2. Classroom discussion of bridges	2. Subjective
	3. Paper bridge experiment	3. Creative
	4. Test paper bridges	4. Subjective/empirically based
	5. Choosing material and re-do paper bridges	5. Creative, subjective, cultural
	6. Presentation of bridges	6. Subjective and cultural
4/Airplanes	1. Watch video clips of airplane landings	1. Observations
	2. Demo of funnel and ball	2. Observations vs. inferences
	3. Create specific paper airplane	3. Empirically-based
	4. Test paper airplane	4. Subjective/empirically-based
	5. Make own paper airplane	5. Creative
	6. Test paper airplane	6. Subjective/empirically-based
	7. Classroom discussion of paper airplanes	7. Creative, subjective, cultural
5/Rockets	1. Read rocket book	1. Observations
	2. Watch video clip of rockets launching	2. Observations
	3. Demo of film canister rockets	3. Observations vs. inferences
	4. Create specific rocket	4. Subjectivity
	5. Add extras (wings, nose, body, etc.)	5. Creative, subjective, cultural
	6. Classroom discussion of rockets	6. Observations vs. inferences, creative

Table 1 continued

Week #/topic	Activities by week	NOS aspects emphasized each week
6/Egg drop	1. Views of nature of science form D	1. Post test
	2. Introduction to egg drop	2. Observations
	3. Selection of materials	3. Subjectivity
	4. Build egg drop	4. Creative, subjective, cultural
	5. Test egg drop	5. Empirically based
	6. Classroom discussion of egg drops	6. Creative, subjective, cultural

2006; Metz 2004; Smith et al. 2000). Using inquiry-based instruction with explicit reflective instruction, we emphasized the empirical, creative, tentative, and subjective, nature of science, as well as helped students distinguish between observation and inferences (See Table 1 for an overview of the activities by week). Throughout the course we provided opportunities for students' previous concepts of science to be challenged through inquiry so their "existing conceptions might not be personally recognized, but also restructured as a result of the experience (Driver et al. 1985)." We connected NOS to the science content areas explicitly by asking questions individually such as, "What observations can you make about your airplanes flight path?" and "How can you use those observations to change your design?" or during classroom discussions we asked questions such as, "How were we acting like scientists today?" or "Why do you think everyone in the class created different cars?" Sometimes we asked students to write their responses to similar questions in their journals with our assistance or pre-service teacher aides. We asked the students to reflect on certain aspects of NOS during class discussions and journal writing (assisting those students who were not able to read or write).

We maintained a similar schedule each class to provide structure for the students (See Table 1). First, we began by engaging students in the discussion about observations and inferences by reading a book and/or showing video clip during which the students were on the floor listening or watching. We followed up with questions about their observations, which allowed discussion regarding the distinction between observation and inference. Second, we gave a brief description of the activities of the day, which generally involved the students building something out of the materials (e.g., building a bridge out of paper and tape) we provided (see Table 1). To encourage inquiry, we asked students to get up from their seats to examine the materials we had made available and if desired, ask for additional materials. After building the item, such as a car, they tested to see how far it would travel or the length of time it took to reach a certain distance. During testing, adult aides assisted students with measuring or timing and helping them to record the data in their journals. Students were often at different points of their inventing, some building, some testing, and some planning. If we had enough adult aides available, we had each of them help small groups of four or five students while the instructors, Authors 1 and 2, moved around the classroom helping to resolve conflicts, and organizing the next activities. Finally, we conducted discussions where students were encouraged to reflect on the target aspects of NOS they experienced during their inventions. During classroom discussions, either Author 1 or 2 took the lead in the discussions with a particular focus of NOS previously planned.

At the beginning of the first session, we randomly selected the students and interviewed them using the pre test of View of Nature of Science Form D (VNOS-D). We conducted the interview according to the recommendations of Lederman et al. (2002), which provided a valid and reliable protocol for assessing young students' views. If the students asked what something meant, we did our best to describe it without leading the students. We repeated this same procedure during the sixth session when we post interviewed students using the VNOS D questionnaire.

The first session focused on "What is the Nature of Science?" We began with a book by Lionni (1997) titled, "The Color of His Own" discussing the nature of a chameleon and used that information to a "nature of me" activity in which students colored an outline of a person with items that make them unique. We then transitioned into the "nature of wheels" and had a classroom discussion posing questions such as, "What makes a wheel a wheel?" and "What makes a wheel different from a door?" with a focus on introducing the words observations and inferences, explicitly correcting the students if they named an inference as an observation and vice versa. Then the students drew a picture of a "good" wheel and a "bad" wheel and describe the differences, again using the terminology observation and inferences. Finally, we had the students create their own wheels and test them making any needed changes to the wheels after testing. During the building of the wheels, we focused on subjectivity of science and how scientists use creativity.

During week two, we focused on observation and inference skills by giving the students multiple opportunities for using these skills. We begin by reading a book about cars in the past. Then we had a class discussion that specifically asks the students to make observations about these cars and infer why scientists would have designed the car this way. This week we included an activity that promoted the students' observation skills and helped them differentiate observation and inference. Author 2 demonstrated a toy car moving and asked questions about observations and inferences. Next, we introduced the car building activity. Each student created a car using the materials we provided such as Styrofoam balls, aluminum cans, etc. Then they tested to see if the car would roll down a ramp and then we provided time to make alterations and re-test the cars. During the testing process, we introduced measuring tape as a scientific tool. Then, we allowed students to present his/her cars to the class and describe the building process. We also allowed the students to work at their own pace so some of the students are building, some journaling, some testing at the same time.

During the third week's session, we continued emphasizing observation and inferences and practicing using scientific tools. Students recorded their data and then could share evidence for the claims they made. Also, we continued to focus on working collaboratively to model subjectivity in science and social context of NOS in a scientific environment. The students began the class by drawing pictures of pictures in their journals. We read a book that described different types of bridges and then we asked them to make observations about these bridges. We assigned the groups to ensure that no one is left without a team. We provided every group with the same materials. The task was to make a paper bridge that can hold a 20 oz. water bottle filled with water. After they made a plan for the bridge, they constructed it. Then they tested the bridge and timed how long the bottle was held using a stopwatch and recorded the data in their journals. After all the teams successfully completed the task, they were allowed to choose another item from the materials provided (i.e. more tape or paper or popsicle sticks) to add to their bridge and then they repeated the test. They were challenged to increase the time the bottle was held. Then the class was brought together for a classroom discussion with a focus on explicitly asking them how they acted like scientists in this activity.

In the fourth week we shifted to demonstrating subjectivity in science. We also continued to provide opportunities for making observations and inferences and to re-examine how scientists use data to inform their future work (tentative nature of science). Another purpose of this session was to foster an uncompetitive environment. We began the class by having the students draw pictures of airplanes in his/her journals. Then we discussed the drawings. We showed the students video clips of airplanes taking off and landing. We simultaneously asked the students to make observations and inferences. After the clips, we demonstrated how a piece of paper can fly and asked them to make observations. Then the students made their own paper airplanes. First, we provided them with instructions so that everyone would have the "same" paper airplane. After they completed this first airplane, they tested them and we measured the distance traveled and time they were in the air. Then we asked the students to design a new airplane in their journals and make predictions about how far the airplane would fly. Then they built this airplane. After they finished building, they tested the airplanes, recorded the data and compared it to their predictions. This activity allowed us to emphasize the use of evidence that can be observed to make inferences from testing or experiments to redesign the invention. Also, this allowed us to reflect on subjectivity where they started from the same information (in this case the same design and same materials) and then they redesigned the different planes that affected the final outcome. Moreover, this week we started to emphasize prediction and expected them to gain the idea that scientists use their imagination when they make predictions. The fifth session focused more on developing inferences from observations. We also explicitly focused on the creativity aspect. Although throughout the class creativity had been modeled implicitly, it was never explicit, until this point. We also reinforced the sociocultural aspect of science by having them work in pairs to make the rockets. We had the students draw pictures of rockets when they arrived to the classroom. Then we read a rocket book and showed them the video clips about rockets and provided time for students to make observations and inferences about the rockets. We then demonstrated the activity that they would be doing which was creating a rocket by putting Alka-seltzer tablets in a film canister that contained water. The students were required to wear goggles while they were watching the demonstration and while they were doing the experiment. Also, we started using an observation and inference data sheet. Students were required to write down in the first column of the sheet what happened in the container when an instructor put an antacid tablet into the water. We reviewed the definition of an observation. Once all students could make their rockets work, we asked them to use pieces of paper to decorate the rockets and determine if it still works the same way. Finally we held a class discussion and we asked them what observations they made and why.

At the beginning of the final session, we administrated the VNOS-D and conducted interviews. For the lesson, we focused on completing the egg drop activity with an overall theme of how we were acting like scientists during the entire program. We asked the students to work in teams of two to create an invention that protects the egg when we drop it from the second floor. We provided them with several materials; however, they had to decide which items to use. Before they dropped their creations, we held a class discussion in which they shared his/her egg drop device and give the rationale of how they create their invention. They then tested the egg drop devices we had a discussion. The students had a chance to share if their eggs were safe. Finally, we asked what we learned about what science is, and what scientists do.

Data Sources and Collection

To determine the influence of our explicit reflective instruction on K-2 students understanding of NOS aspects, we used a variety of data sources. These data sources included: videotaped class sessions, audio-recorded instructor reflections, student journals, and VNOS-D pre- and post-interviews. To track our instruction we videotaped each class session and audio recorded our reflective conversations. After the 6-week course ended, we individually viewed the videos and recorded observations and reflections of the course. We focused on the objective for the course and which NOS aspects we were trying to address, along with how we attempted to meet that objective, and our interactions with the students. We also used the videotapes to ensure that we explicitly emphasized NOS through the use of contextualized and decontextualized science instruction. The reflective conversations occurred immediately after the classes with the focus of the class on students' understanding of the NOS aspect we attempted to teach. We transcribed the conservations verbatim.

We used student journals and views of nature of science form D (VNOS-D) to track views of NOS throughout the course. We used copies of the student journals to track changes in perceptions of NOS elements over time. Students used their journals to make observations, collect data, and reflect in writing or drawings to our prompts. Throughout the course, we used prompts such as "What were some observations of the rocket launch you can make?" to help the students explicitly reflect. We used the journals as evidence for student understanding of the NOS aspects and to determine whether instructional techniques were effective.

Secondly, we used the procedures first described by Lederman and Lederman (2004) and later modified by Akerson and Donnelly (2009) for the VNOS-D with very young children. This protocol is as followed: In a small table groups of 4, adult leaders asked students for responses for individual items on the VNOS-D. The adult leaders wrote down the responses verbatim. They were instructed to ask questions such as, "can you give me an example?" They were instructed not to provide any responses themselves, nor lead the students to a particular response. Lederman and

Lederman describe using this interview approach with small groups of young children because they likely have little knowledge of NOS pre-instruction, and some cannot write their responses on the survey. Akerson and Donnelly (2009) recommended individual assessment of student views and by tracking the verbal responses with the student's name, it made it easy for us to note which student held various ideas. This procedure was conducted on week 2 and week 6 of the program. Additionally, we randomly selected five students to individually interview on week 2 and 11 students were interviewed on week 6. We followed the protocol determined by Lederman to be appropriate and valid for early elementary students. The interviewers did not lead the students in any way. If the students said, "I don't know" the interviewers did not push the students and moved onto the next question. We waited until week 2 in order to receive the signed consent forms from the parents and children. This procedure served two purposes as a (a) baseline of student NOS instruction, and (b) way to help students identify their own ideas. We then transcribed the interviews verbatim. It is also important to note that while researchers have had success with using the VNOS-D in similar age levels (see Akerson and Donnelly 2009) this survey was one component of our data collection.

Data Analysis

In analyzing the data, we used the procedure validated by Lederman et al. (2002). We transcribed the audiotapes of the interviews and reflection sessions verbatim. We analyzed all pre- and post-instruction transcripts and VNOS-D questionnaires to generate profiles of each participant's view regarding the target NOS aspects. We used four ratings including informed, adequate, inadequate, and irrelevant to generate those profiles. We also coded the data sources of reflection sessions, and observation notes using an emergent coding technique paying particular attention to changes made due to our reflective practice and the implementation of those changes. We used traditional qualitative procedures for coding and developing themes (Creswell 2003; Miles and Huberman 1994) into attain a view of the students' understandings of NOS. The VNOS and the individual interviews were coded using an open-coding coding technique to represent, as closely as possible, participants' own words. This open-coding process included segmenting text into meaningful units and assigning code labels to each segment. For example, a broad unit was that the students' felt scientists used creativity in parts of the experiment, which was an overall theme for the more refined code; scientists are creative during designing an experiment. The codes were refined throughout the coding process as new ideas emerged and as similar codes were grouped together into broader themes.

Next, we coded the data sources of reflection sessions, observation notes, and student journals using an emergent coding technique (Miles and Huberman 1994) paying particular attention to changes made due to our reflective practice and the implementation of those changes. Additionally, the researchers coded the data individually, then came together to review the coding and discussed any conflicts. The videotaped lessons were also reviewed to determine whether NOS was explicitly addressed and to examine students' views of NOS that were articulated during the reflective discussion at the conclusion of the day. The researchers coded the data individually, then came together to review the coding and discussed any conflicts.

Finally, we crossed checked our reframed lessons with the student journals and other artifacts to see if the changes affected student learning. We organized our data so that our reflections and reframing could be clearly seen and then provided examples of how our changes influenced students' understandings to NOS. We validated our data using triangulation, negative case analysis and construct validity. We triangulated the data by using multiple forms—student interviews, audio recordings of reflections, observations of the video recordings of the classes, and student journals. This use of multiple forms allowed for multiple perspectives of student understanding through the student journals, observation of classes, and interviews. It also provided multiple opportunities for reflection through audio-recordings of reflection session and observing the video recordings of the classes. Next we triangulated the data by viewing the videotapes and coding separately. This provided both members, who represent different theoretical backgrounds, to individually analyze the data and then come back together to review the analysis. When possible, we provided negative case analysis as a means for strengthening our data. For example, although several students demonstrated that they could differentiate between observations and inferences, we also provided examples of students who could not distinguish between the two ideas. In addition, we strengthened the construct validity to enhance the credibility of our findings through an in-depth description that elucidates the complexities of our processes and interactions that took place during the study. Secondly, in reflective practice there is a risk of rationalization, which would decrease construct validity. Rationalization is "most apparent when a problem is not (cannot) be viewed in other ways such that the existing perspective dominates the practice setting and the problem continues in its present form" (Loughran 2002, p. 33). We protected against rationalization by having two members who co-taught the course as a part of the entire process. By having two members analyze the data independently we reduced the chance we were rationalizing what we saw happening in the class. As well, since we videotaped all the classes, we reflected on these tapes as a way of checking our observations and reflections. We constantly engaged in reflection of our practice, which helped to continually define the concepts we taught. Finally, we engaged in a form of member checking during the coding because we were the teachers of the course.

Results and Interpretations

Throughout the program students developed their understanding of the target aspects of NOS including observation and inference, empirical, tentative, creative, subjective, and social and cultural embedded NOS. We present our results by addressing students' understandings of the target NOS aspects prior to the participation in the program. Next, we present the results by NOS aspect that includes (a) description in class activities that informed specific NOS aspects and (b) examples of evidence from both debriefing at the end of each lesson and post intervention survey that showed the influence of the intervention on students' views of those aspects.

Students' Views of NOS Prior to the Program

Prior to the program, half of the students realized science is not only a body of knowledge, but also a scientific process. Secondly, they believed science is learning about the world through experiments. The pre-survey also revealed that many students already held an adequate view of empirical NOS; they believed that scientists observe and make inferences. Ninety percent of the students articulated that bones and fossils are evidence for the existence of dinosaurs, and scientists use them to infer the physical appearance of dinosaurs. However, partial understandings were found regarding other aspects of NOS. Half of the class believed science was a creative endeavor; however, they could not articulate how scientists apply creativity throughout the scientific process. Regarding the tentative NOS, only one student (second grade) believed science could change when scientists discovered new evidence. No evidence of adequate views of the subjective and cultural NOS was found prior to the program.

After instruction analysis of the interview transcripts and the post-NOS surveys revealed that students retained adequate views of all previously attained NOS aspects. Overall, there was improvement in the understanding of the tentative, creative, subjectivity, and social and cultural embedded nature of science. We found our instruction most influenced the students' understanding of the tentative NOS. We will describe those changes in the following sections.

Development of Students' Views of NOS

In this section we will describe the changes in students' understandings of NOS. We will also describe particular influences on their conceptions of NOS.

Observation Versus Inference

The concept of the distinction between observation and inference was emphasized throughout the program (See Table 1). We used several teaching strategies to teach this particular concept. During week one, we allowed them to practice making observation and inferences by reading a book about different types of wheels followed by the discussion of what makes a wheel different from others. Most of the time, students responded with the inferences merged with observations. This finding is consistent with Akerson and Donnelly (2009) showing the distinction between observation and inference tended to be more difficult than other aspects of NOS for early elementary students to understand. Therefore, we decided to focus more explicitly on NOS aspects beginning with observations and inferences and use that as a starting point to lead into other aspects (Leager 2008). We first gave students multiple opportunities to practice by observing and discussing similarities and differences they saw in the picture books of cars and what they have seen previously in their observations. Second, we continued asking students challenging questions about the cars that they were building to focus their attention on situations where it is possible and not possible to gather data using observations. Finally encouraged students to look for patterns and make generalizations from their data (i.e., inferences). By helping children develop their skills of observation and inference in science while simultaneously explaining the importance of each skill we hoped they would develop a better understanding of how scientists generate knowledge about the world (Hanuscin and Park-Rogers 2008). For the second week's session, we added an activity that allowed us to walk the students through the distinction between observation and inference. We demonstrated the movement of a toy car, where the students were asked to observe what happened when the instructor pushed the car.

Overall, these students could not differentiate inferences from observations. When asked what they observed when the instructor pushed the car, they answered the car moved. However, they started to realize the roles of these two skills in science practice and we make observation through our five senses. For example, Joseph stated that "we use our senses such as sight to observe and scientists do the same thing."

During week three, the evidence showed that students began to develop an understanding of the distinction between observation and inference. For instance, Author 2 mentioned in her reflection "…We discussed different observations of the bridges. The students commented about color, size, detailed descriptions, places, they all transport things…." However, this understanding was not present for all students. Occasionally they included inferences into their observations. For instance, after building bridges that students were required to test, when asked what they observed during the testing, Alex, a second grade student, responded, "The bottle went boom;" while others answered "The tape was not strong enough," indicating that some students were developing better understandings of the distinction between observation and inference than others.

During week five, when an instructor demonstrated an antacid tablet dissolving, the students recorded their observations and inferences on the data sheet. The result from the sheet revealed students' adequate understanding of observations. All fifteen students were able to name observations, such as "It looks smoky" or "bubbles are going up." However, inferences remained a difficult concept. According to the data sheet, only 3 out of 15 students could record both observations and inferences correctly. All three of these students were second grade students. For example, David wrote on his data chart under observations, "bubbles stick to the side" and the corresponding inference, "because of force." Alex also was able to demonstrate his knowledge of observations and inferences when he wrote, "the tablet is getting smaller and smaller" as an observation and the inference, "it is dissolving."

Although the majority of the class could not explicate the distinction between observation and inference, some students were able to give the definition of inference and its role in science. For instance, when asked during the discussion in week five what inference is, Alex responded an inference is "what we think." When asked what we learn in science class and what scientists do during the discussion in the final week, Sarah addressed science is about "what you think and how scientists discover stuff."

Empirical

Throughout the program, we emphasized the empirical NOS by encouraging the students to test their inventions using the tools provided by the instructors, and to modify their pieces to improve the performance of the invention. They were asked to record data in their journals while they were testing, and at the conclusion of the lesson they were asked to share how they used these data to improve their pieces. Moreover, to demonstrate the idea of how scientists collect their empirical data, we provided opportunities for the students to use scientific tools such as measuring tape, and stop watch.

During discussion in week one, four students showed their understanding of empirical NOS. They agreed they acted like scientists when they tested their wheels. They not only used evidence from the test to improve their invention, but also developed the new designs from their peers' ideas. Thomas shared in his journal that he used one of his peers' ideas as the information to change his own wheel. During week three, students were assigned to build and test bridges as a group. In the first round of the invention, all groups were provided with the same materials. After testing and discussing the weaknesses of their bridges, they rebuilt them, and this time they were allowed to select two additional materials to incorporate. During the small group discussion, the students demonstrated their understandings of how to use data from their observations to change their ideas. As Author 1 wrote in her journal,

> One group tried putting a bottle in the middle of their bridge and the bottle fall down, so that they put a wider piece of paper in the middle of the bridge where they had put a bottle. When asked for a reason, they said that they saw the bottle fall down and because the middle part is too narrow so it could not hold the bottle. Then they fold the middle part, and they said, 'so that the bottle can stay on.' Then they tried it and the bottle stayed on.

During week six, when we asked how we acted like scientists, Thomas said, "We were inventing something and making sure and scientists do that. Making and trying to see how it works."

Tentative

Due to the nature of the course, this concept was heavily reinforced as each week students designed and redesigned different inventions. We emphasized the tentative NOS by allowing the students to test and redesign their inventions and draw pictures of their original and final pieces. During the testing session, they were provided the opportunity to collect data from not only their own pieces, but also their peers' inventions. Through this experience, they understood scientific claims could be changed to make improvements in scientific designs. During the discussion in week four, three students demonstrated their adequate view of tentative NOS. The following excerpt provides the evidence of their understanding:

I: How we were acting like scientists today?
Todd: We have to design over and over again.
I: Why?
Roy: Because if one fails we can have another.
Joseph: We design to make something different.

The results from the VNOS-D survey showed after the intervention eight students who had initially believed that science is absolute changed their conceptions to understanding that scientific claims can change toward the end of the program. Nevertheless, the causes of the change were varied. For example, one student believed that scientific knowledge could change because of the knowledge itself and scientists are required to try it several times. He responded to question three of the post survey that “Yes, b/c science is usually changed from thing to thing because some things don’t work and you have to do it over and over”; another student believed that science changed because scientists [people] change the ways they look at it. He said, “Yes, because people come up with different things.” Moreover, one student demonstrated his adequate understanding across several aspects in his response to question 1; he said, “[Science] is where you invent stuff. You try it out, fail, [repeated several time] and finally you get *it.*” Similarly, during week four, Tim articulated during a discussion the class was acting like scientists when “they have to design over and over again.”

Creativity and Imagination

During week one the students were asked to record in their journal how they used their creativity when they were inventing. Three out of nineteen students stated in their journals that they used their creativity when they designed and chose materials to develop their wheels. Jordan mentioned in his journal that he was creative when he used string in different ways than [people] would probably expect. Moreover, Joseph stated that he used his creativity when he was thinking about how to change it.

Throughout the program, we designed lessons that allowed the students to experience creativity’s role in science and how scientists use their creativity in their work. Due to the nature of the course, we centered on scientists being creative during the invention phase, however during the journal activities, we asked questions such as, “Do you think you were creative during all stages of the development?” At the conclusion of the program, data from post-interviews revealed that more than 50% of the students believed that scientists are creative. For example, David described scientists as being creative when, “they invent something that they haven’t seen before.” Also Jackson stated that scientists are creative when, “they analyze data. And experimenting too, and planning because they have to think about what is going to happen. That is using their imagination.”

The intervention had some influence on students’ views of creativity and imagination in science. One student, who initially held an inadequate view of the creative NOS, developed an informed view by the end of the program. When asked in the post-interview whether scientist use creativity and imagination in their investigation, he responded, “Yes, they use it when they are trying to find out what things there are. For example, when trying to figure out the color of dinosaur skin they used their imagination and the bones to figure it out.”

Subjectivity

In week three we designed the invention session for the students to experience the idea of subjective NOS, where scientists have same information/materials; however, they interpret/create different conclusion and inventions. For the first invention they worked in groups of four creating a bridge with the same materials, tested it, recorded the amount of time the bridge suspended a water bottle, and reported the findings to the class. Later they were asked to choose two additional materials to create a new bridge. As we expected, each group chose different materials. During the discussion at the end of the class Joseph demonstrated his adequate view of the subjective NOS. When asked what we did today that was like how scientists work, he responded, “Scientists do not always come up with the same idea.” During week four, we continued emphasizing the subjective NOS by creating paper airplanes from the certain materials and designs provided. After students tested their airplanes, students were asked to use the same materials to create another airplane with their own design.

After the course of 6 weeks, some students improved their views of subjective NOS. The results from pre-survey and interview showed that none of the students were able to give the reason of scientists’ disagreement on the extinction of dinosaur; however, 3 out of 15 students gave explanation that relates to subjective NOS. For example, Jackson’s response referred that the way scientists’ explanations of dinosaur extinction are influenced by different theories each scientist has studied. He mentioned that some scientists have heard about the theory of the meteor but some might not know about it.

Social and Cultural Embeddedness

After reviewing our classroom instruction, we discovered this aspect was the most challenging for us to model to the children. However, we were still able to successful implement several strategies during our teaching. During the invention in the first week, students were asked to create their own wheels individually. They were asked to draw the picture of their first invention and the final piece to see how much they had changed their invention. They were allowed to test and modify their pieces as much as they wanted. At the end of the lesson, they were asked to share their invention and how they changed them. Several students mentioned that they changed their piece in the same way as their peers because they saw it worked well when they tested it. At the conclusion, they all agreed on when asked if scientists use others’ ideas to improve their invention. During week three, we hoped to create a sense of how scientists work in teams and how social context is a central theme in science. In week six, when asked what they would do if they acted like scientists, one student answered, “We [would] change and incorporate others’ ideas to our invention.”

The results from the post intervention VNOS survey reveals there was little improvement on students' understanding of the social and cultural aspect of NOS. When asked about scientists' disagreement on the cause of dinosaur extinction on the post intervention survey, one student, Han, gave an explanation that relates to social and cultural embedded NOS. His response refers to the different beliefs in different countries that influence how the people from those countries interpret data in different ways.

Conclusions

Overall the students participating in the program improved their understanding of the target aspects of NOS through use of explicit reflective instruction. However, the levels of improvement varied across different aspects. Students improved the most in their understanding of the tentative nature of science and the roles of observation in scientific work, although there was still some confusion regarding the distinction between observation and inference. More work needs to be done exploring these specific topics and the role explicit reflective practice can play in identifying the particular problems students have in distinguishing these constructs.

We discovered that explicit reflective instruction provided us with an opportunity to truly learn as we were teaching, as well as recognize and respond to that knowledge as we become more responsive to the needs of the students. Because of the built-in reflective piece, we were able to constantly monitor whether the students understood NOS aspects and alter our instruction to help scaffold them to better understandings. In addition, the topic of invention that we used as the embedded-content to teach NOS served as a good model for the target aspects of NOS (observation and inference, empirical, tentativeness, creativity and imagination, subjectivity, and social and cultural context). By using our pattern of including first inventing, testing, and reinventing, we used the objects we asked them to create each week as the concrete model where the students' were able to experience the importance of those aspects while they were designing, assembling, testing, and redesigning. Each part allowed us to discuss several aspects of NOS and when students revised their designs they were truly experiencing firsthand the tentative NOS. Additionally, the design process during the inventions served as the model for creativity and imagination, and subjectivity of NOS. When the students were asked to draw a picture of their inventions, we modeled creativity and model imagination by asking them to predict the performance of their inventions. This allowed us to emphasize subjectivity of NOS when each of them selected to use different materials for their invention. The testing of their design allowed them to practice their observation and inference, and also a small group discussion during the testing allowed us to determine their ability to differentiate observation and inference. The experience from the redesign allowed us to emphasize the difference between observation and inference, tentativeness, and social and cultural embedded NOS. Finally, the fact that some students used the ideas from their peers to redesign their final invention allowed us to emphasize social and cultural context of NOS.

Implications

The purpose of this study was to determine if K-2 students were able to adequately understand target aspects of NOS. We sought to provide a resource to other teachers who want to improve their young students' understandings of NOS aspects and therefore could use these techniques in their classrooms. By studying our own teaching, we were afforded a unique opportunity of being able to constantly monitor our successes and failures in the classroom at the same time we were reflecting and reframing our lessons in order to improve our teaching. Using this technique, we quickly responded to issues that arose in the classroom and altered our instruction to help alleviate any problems. This study has implications for teachers of early elementary students to include explicit reflective instruction in their teaching of NOS aspects. It demonstrated the importance of this type of instruction as an effective tool for helping young students better conceptualize NOS aspects. We realize we were afforded a unique situation in which we had a limited number of students in an informal setting that allowed us to focus on science for 150 min at a time. There still needs to be more work done in this area to determine how effective this technique is in a traditional classroom setting where the teacher is responsible for teaching all subjects including science. Yet we believe young children are definitely capable of conceptualizing NOS aspects to varying degrees, and it is essential that they receive explicit reflective instruction to help them reach their potentials in these understandings.

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